LITHOLOGICAL AND GEOLOGICAL STUDY OF THE PLIOCENE FORMATIONS IN THE DANUBE-TISZA INTERSTREAM REGION
Part I

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INTRODUCTION

In the central and the southern parts now studied of the Danube—Tisza Interstream Region there are — as subsurface extensions of the Mecsek and the Villány Mts. — three zones of Palaeozoic, chiefly crystalline, and of Mesozoic, mainly sedimentary rocks which, deep-faulted in the east, trend from NE to SW in a rather high structural position *(Figure 1)*. Farther east, two subsidences have developed: the "*Kiskunság Basin*" in the central part of the Interstream Region, close to the Tisza, and the "*Szeged Basin*" in the south [Csiky 1963, Dank 1963].

The thickness of the Late Tertiary and Quaternary basin filling is lesser above the zones of higher structural position, i. e. in the western part of the Danube—Tisza Interstream Region, but it becomes considerable farther east, in the area of the depression. In the latter, under Late Tertiary deposits, an accumulation of Cretaceous-Palaeogene flysch-like sediments is known [Körössy 1962].

All this is well demonstrated *(Figure 2)* by the cross-section made across the Danube—Tisza Interstream Region by G. Csiky [1963], which we completed with the most recent data. The continental deposits of the Helvetian as well as the marine sediments of the Tortonian and the Sarmatian are lacking in many places, the disconformity being further accentuated by postsedimentational erosion. In the initial stage of the Pliocene, the Early Pannonian, an over-all transgression took place, the sediments then deposited overlie unconformably the older rocks.

The Upper Pannonian deposits are also wide-spread throughout the Danube—Tisza Interstream Region. On the right bank of the Danube they are still exposed, but farther east they have subsided to great depths. Their thickness increases from W to E, just as it is the case with the Lower Pannonian [Kertai 1957, Körössy 1962, Csiky 1963, Dank 1963].

After the Upper Pannonian brackish sedimentation, the last marine one in the Region, the Upper Pliocene (Levantine Substage) already witnessed a fluviolacustrine sedimentation of the Danube—Tisza Interstream Region. From the beginning of the Pleistocene, or somewhat later, but at least during much of the Pleistocene, an aeolian sedimentation was active in the central and the eastern parts of the Region. Corresponding to the climatic changes of the Pleistocene, during the glaciations some loess was deposited, while during the interglacials

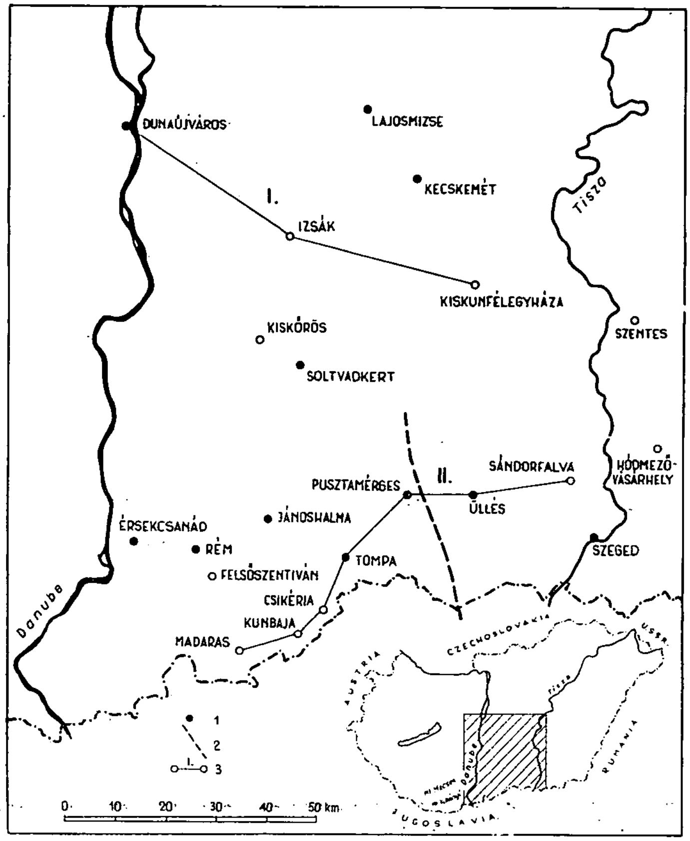

Fig. 1. Layout of the boreholes studied
1. The boreholes studied
2. Pusztamérges fault
3. Section line

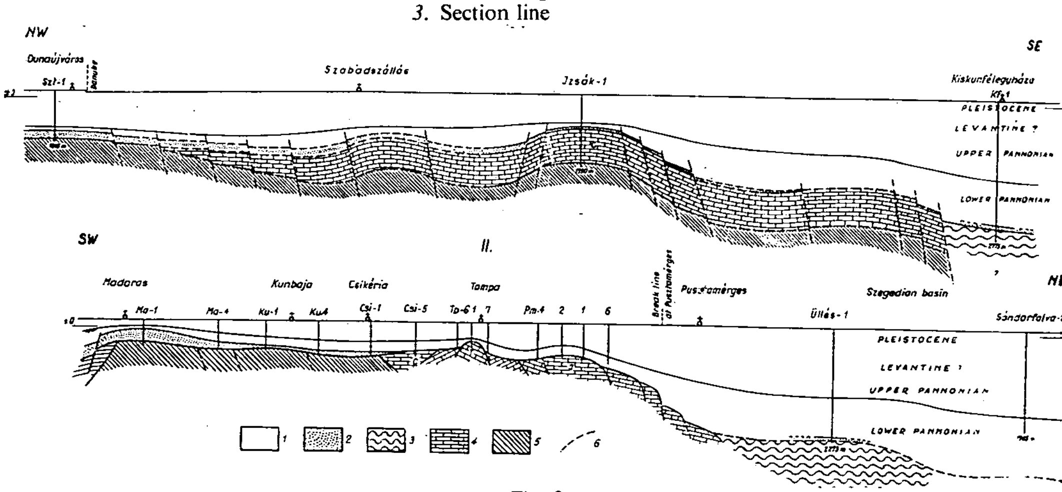

Fig. 2.

and interstadials the westerly winds blew aeolian sands out of the flood-plain of the Danube, which were laid down in the central part of the Danube—Tisza Interstream Region [MIHÁLTZ 1952, 1953, MOLNÁR 1961].

The recent drillings for water and hydrocarbon prospects have enabled us to study the lithology and geology of the Pliocene of the Danube—Tisza Interstream Region more fully than before. The investigations described in the paper have included several aspects thereof.

I. GRANULOMETRIC ANALYSES

The results of the granulometric analyses concerning the Danube—Tisza Interstream Region will be discussed in a chronological order, from W to E. The Pliocene formation in the Hungarian Basin can be divided in two parts — the Pannonian and the Levantine. The Pannonian is further split up into a lower and an upper stage of sedimentation [KÖRÖSSY 1962].

a) Granulometric composition of the Lower Pannonian sediments. The granulometric composition could be determined for a few samples only, owing to the diagenesis of the sediments. The results obtained for these samples are shown on sheet A of *Figure 3*, and in *Table 1.* A comparison by numbers of the granulometric curves and those given in the Table will permit to identify the drilling and the depth, from where the samples were taken. The sites of drillings are also shown in *Figure 1.* For those of the Lower Pannonian sediments, for which a carbonate content higher than 30 per cent was found, only the insoluble residue was analysed *(Table 1).*

The few data available are insufficient for a comparison, but they do indicate that in the region of Kecskemét the Lower Pannonian sedimentation was more unsteady than in the structurally elevated part (area between Rém and Pusztamérges) of the Danube—Tisza Interstream Region.

b) Granulometric composition of the Upper Pannonian sediments. The investigations performed on samples from Kecskemét. Lajosmizse, and Soltvadkert lying farther north in the Danube—Tisza Interstream Region have shown that the sedimentation had undergone rapid changes *(Figure 3, B—C).* A great number of samples with two concentration peaks were found *(Table 1, M_2)*, which is due to the alternation of thin layers because of the very frequent rhythmicity of sedimentation. For sampling the thin layers could not be separated, so that the curves reflect their averages. The oscillation of sedimentation was not of great amplitude, as there is hardly any difference in the grain size of the strata. In case of fine silt (0,005—0,02 mm ∅), along with the main peak the subsidiary one also falls within the size range of the fine silt, or possibly within that of clay (0,05 mm ∅). Major changes are marked by the appearance of sand layers.

Farther south from Soltvadkert the deposition of finer sediments can be observed *(Figure 3*, curves *23, 24, 25).* This holds true even more markedly for the

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Fig. 2. Geological sections across the Danube-Tisza Interstream Region (adopting data of G. CSIKY, 1963).

1. Pliocene and younger formations
2. Miocene formations
3. Upper Cretaceous-Palaeogene flysch-like sediments
4. Mesozoic formations (T=Triassic, J=Jurassic, C=Cretaceous).
5. Palaeozoic formations
6. Fault line.

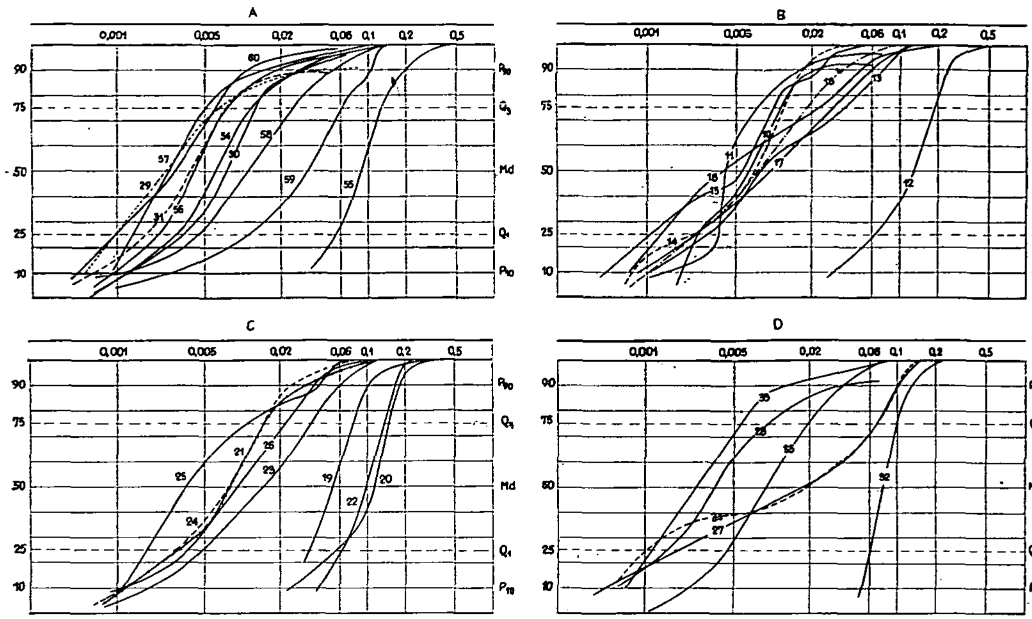

Fig. 3. Granulometric curves of Lower (A) and Upper (B, C, D) Pannonian sediments. (The numbers beside the curves permit identification with boreholes and depths shown in *Table 1*).

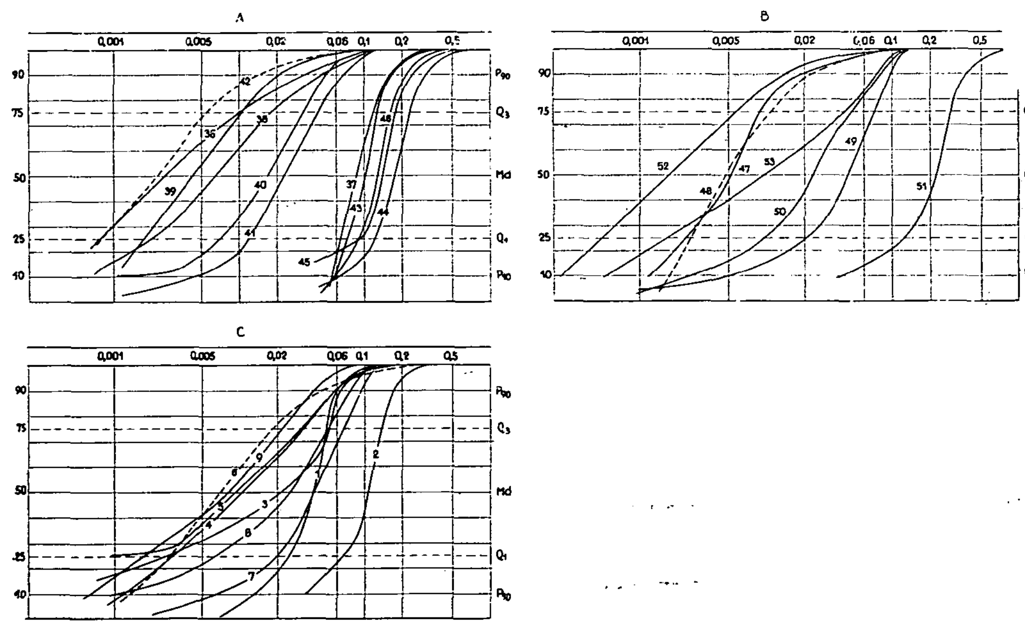

Fig. 4. Granulometric curves of the Upper Pannonian (A, B), Levantine and Pleistocene (C) sediments.

TABLE I

Number	Boring: Locality	Boring: Depth m	P_{10}	Q_1	Md	M_1	M_2	Q_3	P_{90}	So $So = \sqrt{\frac{Q_3}{Q_1}}$	K $K = \frac{Q_3 - Q_1}{2(P_{90} - P_{10})}$	Sk $Sk = \frac{Q_1 \cdot Q_3}{Md^2}$	$CaCO_3$ %	Type of Sediment	Age	
1.	Érsekcsanád—1	30—35	0,013	0,025	0,04	0,04	—	0,05	0,06	1,43	0,27	0,78	30,9	L.	Pleistocene	
2.	Rém—1	35—40	0,042	0,082	0,013	0,15	—	0,17	0,22	1,44	0,25	0,82	13,2	S. S.		
3.	Érsekcsanád—1	200—204,5	—	0,0024	0,022	0,023	—	0,054	0,066	4,74	—	0,42	2,2	C. Si.	PLIOCENE	Levantine
4.	Jánoshalma—7	200—204,5	0,0012	0,0031	0,011	0,013	—	0,033	0,055	3,25	0,28	0,60	17,7	F. Si.		
5.	Pusztamérges—2	148—153	—	0,0015	0,0095	0,012	—	0,031	0,062	4,53	—	0,52	19,9	F. Si.		
6.	Üllés—1	280—286/a	0,0013	0,0027	0,0067	0,0080	—	0,019	0,045	2,65	0,19	1,14	14,2	F. Si.		
7.	Üllés—1	350—356	0,0057	0,02	0,04	0,04	—	0,068	0,095	1,84	0,27	0,84	15,0	C. Si.		
8.	Üllés—1	718—723/a	0,00075	0,0062	0,025	0,022	—	0,052	0,077	2,89	0,30	0,52	20,8	C. Si.		
9.	Üllés—2	563—568	0,00062	0,0017	0,008	0,008	—	0,022	0,042	3,60	0,25	0,58	20,2	F. Si.		
10.	Dunaújváros—1	152—154	0,0019	0,0026	0,0065	0,0078	0,0022	0,012	0,023	2,15	0,20	1,03	31,0	F. Si.		UPPER PANNONIAN
11.	Dunaújváros—1	251—253	0,0012	0.0038	0,0044	0,005	0,0020	0,0078	0,016	1,42	0,14	1,53	21,1	CL.		
12.	Dunaújváros—1	451—453	0,03	0,062	0,13	0,15	—	0,18	0,24	1,70	0,28	0,66	17,7	S. S.		
13.	Dunaújváros—1	551—553/a	0,0011	0,003	0,008	0,0065	0,0095	0,036	0,075	3,46	0,22	1'69	18,6	F. Si.		
14.	Dunaújváros—1	553—557	0,0008	0,0024	0,007	0,008	0,0009	0,012	0,027	2,23	0,18	0,59	33,2	F. Si.		
15.	Dunaújváros—1	603—605	0,00057	0,0011	0,0057	0,008	$\begin{Bmatrix} 0,0012 \\ 0,025 \end{Bmatrix}$	0,01	0,023	3,02	0,20	0,34	26,6	F. Si.		
16.	Lajosmizse—3	505—510/b	0,00072	0,0013	0,0042	0,0019	0,024	0,043	0,047	5,75	0,45	0,32	26,6	CL.		
17.	Lajosmizse—3	700—705	0,00082	0,0023	0,0092	0,013	—	0,038	0,057	3,80	0,27	0,89	28,8	F. Si.		
18.	Lajosmizse—3	800,5—806	0,0011	0,0024	0,0075	0,0098	—	0,018	0,035	2,73	0,23	0,76	22,1	F. Si.		
19.	Kecskemét Ny—1	646—651/b	—	0,034	0,053	0,058	—	0,087	0,11	1,60	—	1,05	24,4	F. S.		
20.	Kecskemét Ny—1	760—765/a	0,026	0,057	0,11	0,13	—	0,15	0,19	1,62	0,28	0,71	19,9	S. S.		
21.	Kecskemét Ny—1	760—765/b	0,0012	0,003	0,008	0,0087	—	0,015	0,034	2,23	0,18	1,02	24,4	F. Si.		
22.	Kecskemét Ny—1	901—907	0,042	0,064	0,1	0,11	—	0,13	0,17	1,43	0,26	0,83	28,8	S. S.		
23.	Soltvadkert—1	557—562	0,0018	0,0048	0,015	0,014	—	0,035	0,062	2,70	0,25	0,74	29,8	F. Si.		
24.	Soltvadkert—1	646—651/a	0,0011	0,0029	0,008	0,008	0,047	0,015	0,027	2,27	0,23	0,69	24,4	F. Si.		
25.	Soltvadkert—1	912—917	0,0011	0,0018	0,0033	0,0042	—	0,015	0,042	2,97	0,16	0,25	28,8	CL.		
26.	Érsekcsanád—1	252—257	0,0011	0,0036	0,009	0,0012	—	0,022	0,039	2,47	0,24	0,98	26,6	F. Si.		
27.	Rém—2	201—206	0,0005	0,0018	0,0018	0,016	—	0,065	0,1	6,0	0,32	0,36	6,6	F. Si.		
28.	Rém—2	450—455	0,00055	0,0014	0,0035	0,0045	—	0,0087	0,027	2,50	0,13	1,33	26,6	CL.		
32.	Jánoshalma—2	300—304	0,053	0,062	0,08	0,082	—	0,1	0,13	1,27	0,25	0,97	19,9	F. S.		
33.	Jánoshalma—7	450—455	0,0007	0,0011	0,0025	0,0025	0,001	0,0056	0,13	2,25	0,16	0,99	28,8	CL.		
34.	Tompa—7	302—307,5	0,0005	0,001	0,019	0,055	—	0,077	0,095	2,76	0,40	0,41	26,6	C. Si.		
35.	Pusztamérges—2	200—205,5	0,0021	0,0044	0,009	0,011	—	0,19	0,038	2,08	0,20	1,03	22,1	F. Si.		
36.	Pusztamérges—2	250—255,5	—	0,00075	0,0025	0,0032	—	0,0098	0,033	3,60	—	1,11	4,4	CL.		
37.	Pusztamérges—5	450—455/a	0,055	0,062	0,090	0,11	—	0,14	0,17	1,50	0,34	1,08	4,4	S. S.		
38.	Üllés—1	760—766/a	0,00065	0,0019	0,0064	0,0072	—	0,018	0,048	3,07	0,17	0,83	27,5	F. Si.		
39.	Üllés—1	883—839/b	0,001	0,0018	0,0044	0,005	—	0,01	0,02	2,25	0,22	0,94	18,6	CL.		
40.	Üllés—1	1064—1070/b	0,0013	0,0065	0,017	0,02	—	0,032	0,048	2,25	0,27	0,75	18,7	F. Si.		
41.	Üllés—1	1217—1223	0,0044	0,011	0,023	0,024	—	0,044	0,069	2,0	0,26	0,92	23,0	C. Si.		
42.	Üllés—2	776—782/b	—	0,0008	0,0023	0,0025	—	0,0057	0,016	2,67	—	0,86	33,2	CL.		
43.	Üllés—2	1194—1200	0,057	0,074	0,1	0,11	—	0,13	0,17	1,32	0,25	0,96	19,9	S. S.		
44.	Üllés—7	1232—1237	0,063	0,12	0,18	0,19	—	0,23	0,32	1,39	0,21	0,85	15,5	S. S.		
45.	Üllés—7	1317—1323	—	0,09	0,14	0,16	—	0,18	0,24	1,43	—	0,82	15,5	S. S.		
46.	Üllés—8	1362—1367	0,058	0,09	0,13	0,14	—	0,16	0,22	1,33	0,22	0,85	9,7	S. S.		
47.	Szegedi Textil—m.	996—997,5/b	0,0011	0,0022	0,0052	0,0053	—	0,009	0,02	2,02	0,18	0,73	13,2	F. Si.		
48.	Szegedi Textil—m.	997,5—1000/a	0,0017	0,0025	0,0048	0,0052	—	0,011	0,023	2,10	0,20	1,0	11,1	F. Si.		
49.	Szegedi Textil—m.	997,5—1000/b	0,005	0,021	0,045	0,05	0,017	0,072	0,098	1,85	0,27	0,74	8,9	C. Si.		
50.	Szegedi Textil—m.	1500 m	0,0026	0,01	0,023	0,06	—	0,048	0,081	2,18	0,24	0,91	0,0	C. Si.		
51.	Szegedi Textil—m.	1600 m	0,04	0,12	0,22	0,24	—	0,29	0,38	1,55	0,25	0,72	8,9	M. S.		
52.	Szeged, Székelysor	1193—1194	0,00024	0,00052	0,0018	0,0024	—	0,0058	0,014	3,32	0,19	0,93	2,2	CL.		
53.	Szeged, Székelysor	1490—1494/a	0,00055	0,0016	0,0095	0,011	–	0,043	0,075	5,18	0,28	0,76	31,0	F. Si.		
54.	Kecskemét Ny—1	1169—1174	0,0013	0,003	0,0062	0,0062	—	0,012	0,028	2,0	0,17	0,94	22,1	F. Si.		Lower Pannonian
55.	Kecskemét Ny—1—	1182—1186/a	0,085	0,0055	0,090	0,1	—	0,13	0,2	1,57	0,30	0,88	33,2	F. S.		
29.	Rém—2	550—554	0,0005	0,0009	0,0024	0,0034	—	0,006	0,047	2,58	0,55	0,93	48,7	CL.		
30.	Rém—2	610—614,5	0,0012	0,0033	0,0074	0,0078	—	0,013	0,04	1,98	0,12	0,78	66,4	F. Si.		
31.	Rém—2	665—669	0,00065	0,0017	0,0038	0,004	—	0,0075	0,06	2,10	0,49	0,88	66,4	CL.		
56.	Rém—2	700,5—704,5	0,00095	0,0021	0,004	0,0042	—	0,0072	0,02	1,85	0,13	0,94	62,0	CL.		
57.	Jánoshalma—7	679—684	0,00095	0,0013	0,0025	0,0032	—	0,005	0,014	1,95	0,19	1,04	51,8	CL.		
58.	Tompa—7	449,5—455	0,0011	0,0045	0,011	0,012	—	0,025	0,054	2,35	0,19	0,92	11,1	F. Si.		
59.	Pusztamérges—2	526—531	0,0028	0,011	0,033	0,030	0,11	0,06	0,11	2,33	0,23	0,61	33,2	C. Si.		
60.	Pusztamérges—5	625—630	0,00047	0,001	0,0028	0,0055	—	0,006	0,011	2,45	0,23	0,76	18,9	CL.		

CL. = CLAY = 0,005 > mm ⌀, F. Si. = FINE SILT = 0,005—0,02 mm ⌀, C. Si. = COARSE SILT = 0,02—0,06 mm ⌀, L = LOESS = 0,02—0,05 mm ⌀, F. S. = FINE SAND = 0,06—0,1 mm ⌀, S. S. = SMALL SAND = 0,1—0,2 mm ⌀, M. S. = MEDIUM SAND = 0;2—0,05 mm ⌀

Upper Pannonian sediments of higher structural position between Érsekcsanád and Tompa in the south, where only clay, fine and coarse silts as well as fine sand occurred and no coarser sediment was encountered *(Figure 3, C—D*, curves *27—34)*.

Pusztamérges represents a transition, between the high- and deep-structural areas. Predominantly fine-grained sediments were still found there, but they were already associated with small sands *(Figure 2*, curve *D 35, Figure 4*, curves *A 36—37)*.

In the "Szeged Basin" at Üllés and Szeged all the sediment types ranging from clay to medium sand are available. By the way, medium sand was discerned there only *(Figure 4*, curves *A—B 38—53)*. Along with the deeper structural position of the Pannonian sediments, this fact also shows changes in the conditions of sedimentation.

c) Granulometric composition of the Levantine sediments. The dating of the deposits under consideration is rater uncertain in many places. The sediments deposited in the time span between the marine basin filling of the Pannonian and the fluviatile one of the Pleistocene are classified as Levantine, adopting, here too, the stratigraphic scheme worked out by the National Oil and Gas Industry Trust (1950—1964). The samples analysed have yielded variable curves having no similarity one with another, as a contrast with those obtained for the Lower Pannonian and for a part of the Upper Pannonian. They are indicative of more unbalanced conditions of sedimentation fed by the rivers that entered the Levantine Lake *(Figure 4*, curves *C 3—9)*.

d) Granulometric composition of the Pleistocene deposits — For comparison, some Pleistocene samples were also analysed. These have consisted of loess or small sand which are characteristic for their prominent sorting *(Figure 4*, curves *C 1—2)*.

II. STATISTICAL EVALUATION OF THE GRANULOMETRIC ANALYSES

First of all the evaluation of the granulometric curves will be given. P_{10} is the grain size for 10 per cent, Q_1 for 25 per cent, Md for 50 per cent, Q_3 for 75 per cent, P_{90} for 90 per cent of the total material sampled. M_1 is a representative grain size understood as the grain diameter occurring most frequently in the sample. It lies in the centre of the curve, at its inflexion.

1. The value most commonly used in sedimentary petrological statistics is that of sorting which was calculated by using the formula of Trask given in *Table 1*. If the sorting, the *So* values, were 1, the sediment would contain only grains of uniform size. Since this is not the case in Nature, so higher values are obtained.

According to Trask, if *So* is lower than 2.5, the sediment is well-sorted; if it is about 3, the sediment has a normal sorting; and values higher than 4.5 would indicate a poorly sorted sediment. Füchtbauer [1959] has further developed the method for the various types of sediments.

The *So* scales are indicated on the left side of the graphs. At the bottom the serial numbers from *Table 1* and from the granulometric cuıves are given. The numerals with an asterisk indicate curves with two concentration peaks (curve *5—8*).

a) So values of clay sediments from the Danube—Tisza Interstream Region. The Lower Pannonian clays have *So* values as low as the range between 1,85 and 2,85. They include accordingly few grain size classes. Clay is a type of sediment in which the proper clay is associated with several other grain size classes present in varying amounts. The low values now obtained for the material sampled prove therefore that during the deposition of the Lower Pannonian sediments the southwestern part of the Danube—Tisza Interstream Region witnessed a low-rate, undisturbed, steady sedimentation *(Figure 5,* curves *29—60).* (Only this area was sampled and tested.)

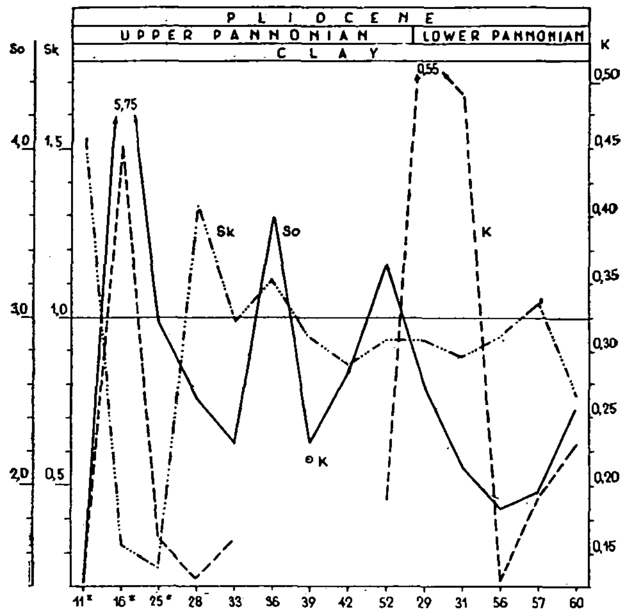

Fig. 5. Values of *So, Sk,* and *K* obtaine for the Lower-Upper Pannonian and Levantine sediments.

The sorting of the Upper Pannonian clays is characterized by its wider range of variation: 1,42—5,75 *(Figure 5,* curves *11—52).* This oscillation of *So* values proves conditions of sedimentation more variable as compared with the Lower Pannonian. Changes of bathymetric conditions of the sea have taken place rapidly. No Levantine or Pleistocene clay was examined.

b) Most of the samples analysed were composed of fine silts.

The Lower Pannonian fine silts are characterized, like the Lower Pannonian clays, by a good sorting with *So* values ranging from 1,98 to 2,35. which testifies to the same fact as the low *So* values obtained for clay do *(Figure 6,* curves *30—58).*

The *So* values, 2.1 and 6.0 alternatingly, obtained for the fine silts of the Upper Pannonian also suggest rapid changes in sedimentation *(Figure 6,* curves *10—53).*

The *So* values of the fine silts of the Levantine also show a wide range of variation, from 2,65 to 4,55, i. e. an average value likewise higher, which proves less sorting and sedimentation of variable facies *(Figure 6,* curves *4—9).*

c) The sorting of the Lower Pannonian coarse silts is good in spite of the double peaks obtained *(Figure 7,* curve *59).*

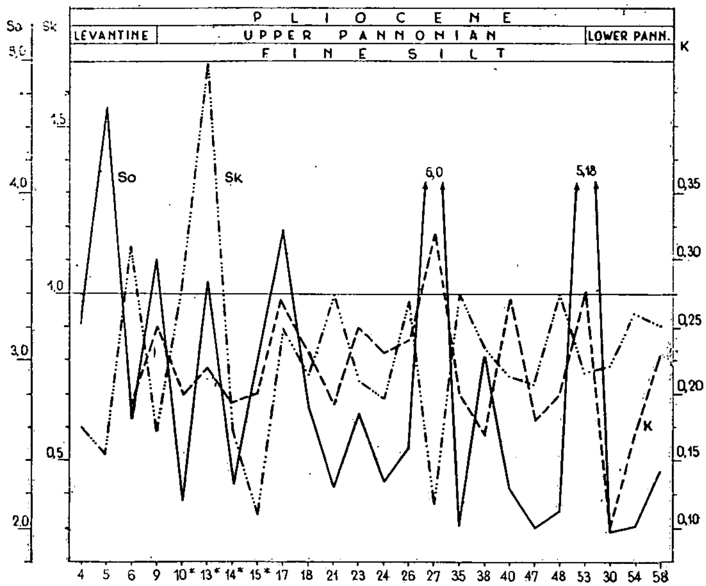

Fig. 6. Values of *So*, *Sk* and *K* obtained for the Lower and Upper Pannonian and Levantine fine silt sediments.

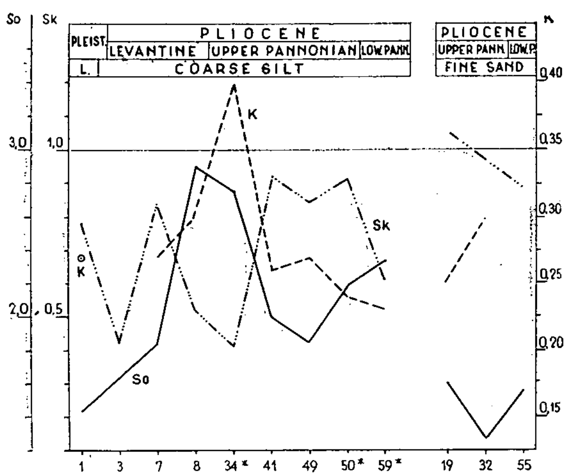

Fig. 7. Values of *So, Sk,* and *K* of different aged coarse silt and fine sand.

The Upper Pannonian coarse silts yield varying *So* values, like the other synchronous sediments do. The coarse silts of the Levantine are characterized by the same values *(Figure 7,* curves *3—50).*

d) The *So* values obtained for the few samples of Lower and Upper Pannonian fine sand vary between 1,27 and 1,6, a proof of a very well-sorted sediment *(Figure 7*, curves *19—55)*.

e) The *So* values of the Upper Pannonian and the Pleistocene small sands vary from 1,32 to 1,70, they are thus very low. For the medium sand of the Upper Pannonian a value of 1,55 was obtained, which also indicates a well-sorted sediment *(Figure 8*, curves *2—51)*.

2. *Kurtosis is an expression for the sharpness of peaks of the granulometric curve.* It gives the comparison of the central extension of the granulometric curve to its total extension, i. e. the ratio of the curve part of the non-quartile grain com-

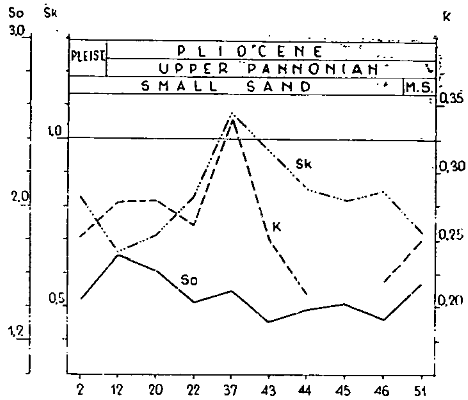

Fig. 8. Values of *So*, *Sk*, and *K* obtained for the small sands of the Upper Pannonian and the Levantine and for the medium sands of the Upper Pannonian.

position is compared to that of the quartile one. Its value is calculated by using the formula form *Table 1*. If the value of *K* is higher, the curve part of the non-quartile grain composition will be steeper (shorter), — if the value of K is lower, it will be more flattened (longer).

The *K* values of the clays from the Danube—Tisza Interstream Region are characterized by their wide range of variation: 0,13—0,55 *(Figure 5*, a scale of *K* values is given on the right side of the graph). The lacking *K* values could not be calculated, as during analysis the curve did not attain 10 per cent (P_{10}).

The *K* values obtained for the fine silts of the Lower Pannonian are still rather variable, those obtained for the Upper Pannonian, 0,17—0,32, being already more steady. Irrespective of the latter prominent figure, they vary within a range as narrow as 0,17—0,27 *(Figure 6)*.

The coarse silts and sands have yielded *K* values which are still rather high *(Figures 7—8)*.

It can thus be stated that the Pliocene sediments from the Danube—Tisza Interstream Region yield rather variable K values, involving in some cases a smaller, in others a greater non-quartile fraction, i. e. they reflect unsteady conditions of sedimentation.

3. *Skewness* (*Sk*) may diverge from the medium size range either towards the finer grain fraction, or towards the coarser one *(Figures 3—4)*. If *Sk* equals 1, we have to do with a curve diverging towards the coarser grain fraction; and if

TABLE 2

Number	Boring		Dominantly Magmatic Minerals										Dominantly Metamorphic Minerals													Other Minerals				Weathered Minerale	Total Quantity of the Heavy—Minerals in the Examined Fraction	Diameter of Examined Fraction in MM	Dominant Grain Diameter MM
	Locality	Depth m	Hypersthene	Other Rhombic Piroxenes	Augite	Diopside	Basaltic Hornblende	Magnetite	Biotite	Apatite	Titanite	Zircon	Chlorite	Tourmaline	Epidote	Zoizite	Rutile	Hornblende	Actinolite—Tremolite	Anthophyllite	Garnet	Staurolite	Andalusite	Cyanite	Glaukophane	Calcite-dolomite	Pyrite	Limonite	Other Micas				
1.	Dunaújváros—1	103—105	0,7	3,5	1,4	6,2	—	0,7	—	0,7	—	—	24,3	1,4	2,8	—	0,7	—	—	—	2,1	—	—	0,7	—	0,7	0,7	4,1	6,2	42,4	0,8	0,1—0,2	0,06—0,1
2.	Dunaújváros—1	451—453	—	3,4	1,4	2,1	—	0,7	—	4,7	—	—	16,2	1,4	0,7	—	—	—	—	—	29,8	2,1	—	0,7	—	8,2	—	2,1	0,7	25,8	1,1	0,1—0,2	0,1—0,2
3.	Dunaújváros—1	500—502	0,8	0,8	0,8	—	—	0,8	—	2,3	—	—	66,5	0,3	—	—	—	—	—	—	2,3	—	—	—	0,8	5,4	0,8	4,7	4,7	8,5	0,5	0,1—0,2	0,1—0,2
4.	Dunaújváros—1	651—653	—	—	—	—	—	—	—	—	—	—	54,2	—	—	—	—	—	—	—	—	—	—	—	—	20,8	—	2,1	4,1	18,8	2,6	0,1—0,2	0,06—0,1
5.	Dunaújváros—1	800—803	—	—	—	—	—	1,1	88,6	—	—	2,0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,1	—	7,2	0,07	0,1—0,2	2,0—10,0
6.	Kecskemét Ny—1	213—215	1,2	2,4	10,4	3,0	3,6	4,8	—	—	—	—	6,8	0,6	1,8	—	—	4,8	1,2	1,2	16,4	1,8	0,6	1,2	—	0,6	0,6	3,6	—	33,4	5,0	0,1—0,125	0,06—0,1
7.	Kecskemét Ny—1	646—651	—	—	—	—	—	2,4	—	—	—	—	59,6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,6	17,4	19,0	5,3	0,1—0,125	0,06—0,1
8.	Kecskemét Ny—1	760—765	—	2,5	1,9	8,1	0,6	1,9	—	3,7	0,6	—	24,6	1,9	1,2	1,2	0,6	—	—	—	15,0	0,6	0,6	1,9	—	6,9	—	3,1	3,7	19,4	2,8	0,1—0,125	0,1—0,2
9.	Kecskemét Ny—1	901—907	—	—	0,7	—	—	2,0	—	8,0	—	—	57,7	2,0	—	0,7	—	—	—	0,7	13,5	—	—	0,7	—	4,0	—	2,0	4,0	4,0	1,2	0,1—0,125	0,1—0,2
10.	Kecskemét Ny—1	1182—1186	0,5	—	—	1,5	0,5	2,5	—	7,1	—	0,5	47,9	1,0	3,1	—	—	—	—	—	19,7	1,0	—	—	—	4,0	—	2,0	1,5	7,2	1,4	0,1—0,125	0,06—0,1
11.	Kecskemét Ny—1	1567—1571	—	—	—	—	—	—	—	—	—	—	31,2	—	—	—	—	—	—	—	—	—	—	1,6	—	—	0,9	—	4,9	61,5	1,7	0,1—0,2	0,06—0,1
12.	Jánoshalma—7	300—304	—	0,7	1,3	1,3	—	—	—	1,3	—	—	56,4	—	1,3	—	—	0,7	1,3	—	2,0	0,7	—	0,7	—	2,7	8,8	4,1	9,3	7,4	0,8	0,1—0,125	0,06—0,1
13.	Tompa—7	197—202,2	—	2,6	3,1	3,6	—	2,1	—	5,7	—	—	29,0	1,6	5,2	—	—	9,8	5,7	—	5,2	1,0	—	0,5	—	1,6	—	0,5	1,0	21,8	0,9	0,1—0,2	0,06—0,1
14.	Pusztamérges—5	450—455	—	—	0,7	—	—	—	—	0,7	—	—	79,3	—	2,2	—	—	0,7	0,7	—	—	—	—	—	—	—	—	0,7	3,6	11,4	0,7	0,1—0,2	0,06—0,1

it is lower than 1, with one diverging towards the finer fraction (values of *Sk* in *Table 1)*. The skewness of the Lower Pannonian clays is low, that of the Upper Pannonian ones being variable in the N of the Danube—Tisza Interstream Region, but steady elsewhere. *(Figure 5*, scale of *Sk* values on the left side of the diagram). The unsteadiness of *Sk* values fiurnishes a further evidence of rapid changes in the conditions of sedimentation.

The skewness obtained for fine silts is prominent in the more northerly part of the Danube—Tisza Interstream Region, but is more steady elsewhere, just as was the case with clays,

The curves of coarse silts show skewness merely towards finer grain sizes *(Figure 7)*. The curves of fine sands are nearly symmetric, while the small sands, all but sample Nr. 37, diverge towards the finer grain size fraction *(Figure 8)*.

III. INVESTIGATION OF HEAVY MINERALS

Information on the composition of heavy minerals in the Late Tertiary and Quaternary deposits of the Hungarian Basin has been furnished in several papers (see *Figure 9* showing the boreholes worked up) [Szabó 1955, Molnár 1961, 1962, 1964, 1965].

Having completed the earlier data with the most recent results obtained for the heavy mineral composition of sediments from the Danube—Tisza Interstream Region, we were able to point out the main directions of transport during the Pliocene and the Pleistocene within the Hungarian Basin *(Table 2, Figure 9)*. During the Pannonian, sediments rich in chlorite were introduced from the West into the area of the Danube—Tisza Interstream Region. Such a composition is exhibited by samples Dunaújváros 1—4, Kecskemét 7—11 as well as the samples from Jánoshalma, Tompa, Pusztamérges (see *Table 2*).

At the same time, in the southern part of the Trans-Tisza Region sediments deriving from the E were deposited. Their actual direction of transport is not yet known, that is why it has not been plotted. The composition of these sediments is characterized, along with chlorite, by a varied assemblage of metamorphic heavy minerals. The sediments deriving from two different directions wedge out along the line of the Tisza, near Szentes, Sándorfalva, and Szeged. This phenomenon culd be made well evident by drilling in the afore-mentioned places. The sediments deposited at Pusztaszöllös, Csanádapáca were removed from NE, in part from the crystalline area that had remained in a higher structural setting in the Trans-Tisza Region. They are also characteristic for the abundance of chlorite *(Figure 9*, curve *2)*.

The Levantine and Pleistocene deposits of the Danube—Tisza Interstream Region were transported from NW, from a source area with a geological setting similar to that of the area drained by the Danube at present. (In the Pleistocene the westerly winds blew sands out of the bed of the Danube and laid them down in form of aeolian sands farther east.) They show nearly the same composition as the Danube alluvium does. An example of this composition is sample 6 *(Figure 9*, curve *3)*.

In the same period, sediments of varied compositions consisting predominantly of igneous minerals were deposited in the Trans-Tisza Region. They were introduced partly by pre-existing palaeostreams, partly by the present rivers *(Figure 9*, curves *4—7)*. An additional characteristic feature of these sediments in the S of the Trans-Tisza Region is the fact that the abundance of the metamorphic minerals tends to decline upwards. Throughout the Trans-Tisza Region, particularly three minerals have a diagnostic value. These are hypersthene and augite in the northern Trans-Tisza Region and hypersthene, augite, and basaltic amphibole in the southern Trans-Tisza Region.

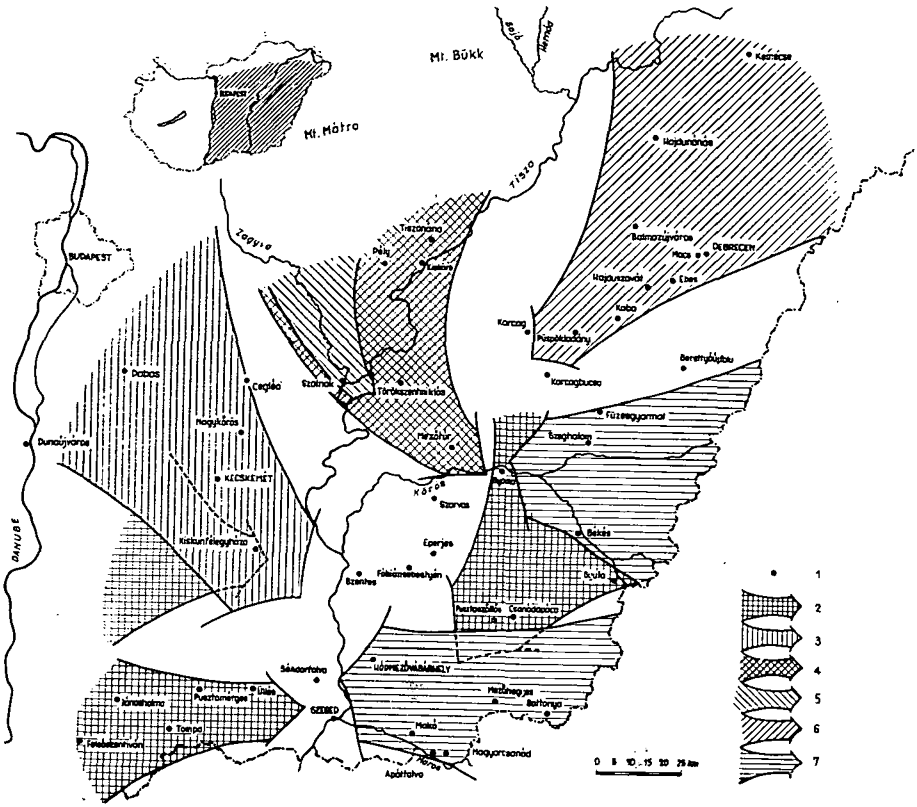

Fig. 9. Directions of transport during the Pliocene and the Pleistocene in the Hungarian Basin.
1. Sites of the boreholes studied
2. Directions of transport during the Pannonian in the Danube-Tisza Interstream Region and the Trans-Tisza Region.
3. Direction of transport by the Danube.
4. Direction of transport by the palaeo—Zagyva—Sajó
5. Direction of transport by the Zagyva
6. Direction of transport by the Maros—Kőrös.

CONCLUSIONS

1. The granulometric composition of the Lower Pannonian sediments is indicative of rapid changes in sedimentation in the northern part of the Danube—Tisza Interstream Region, and of a low rate, more quiet sedimentation in the SW.

The granulometry of the Upper Pannonian formation suggests an unsteady sedimentation in the N, the region of Dunaújváros and Kecskemét and the "Szeged Basin", and a less disturbed sedimentation in the SW, between Érsekcsanád and Tompa.

The Levantine formation exhibits a granulometry of varying facies, the Pleistocene deposits show an aeolian sedimentation.

2. The sorting of the Lower Pannonian clays and fine silts is rather high, that of the Upper Pannonian and Levantine clays, fine silts and coarse silts shows more or less fluctuation which proves that in the Upper Pannonian and the Levantine the sedimentation must have been more disturbed, more unsteady (changes in the bathymetric conditions of the sea). The changes were not too great, since the intercalated sands are well-sorted.

3. The kurtosis of the Lower Pannonian sediments is rather variable, that of the Upper Pannonian and Levantine ones being more balanced, which holds particularly true for the fine and coarse silts and the fine sands.

4. The skewness of the Lower Pannonian clays is low, that of the Upper Pannonian clays recording more changes in the northern part of the Danube—Tisza Interstream Region. The skewness obtained for the Lower and the Upper Pannonian fine silts is less pronounced, especially so in the southern part of the Danube—Tisza Interstream Region. The fine silts of the Levantine show an unsteady skewness, the coarse silts and the sands are skewed but towards the finer grain fraction.

5. The analysis of the samples for heavy minerals has confirmed former suggestions as to the derivation of the Pannonian deposits of the western Danube—Tisza Interstream Region from a western source area. The heavy minerals contained in the Levantine and Pleistocene sediments suggest source area corresponding with or nearly similar to that drained by the Danube.

REFERENCES

Csiky, G. [1963]: A Duna-Tisza köze mélyszerkezeti és ősföldrajzi viszonyai a szénhidrogénkutatások tükrében. — Földrajzi Közlemények, 19—36.

Dank, V. [1963]: Stratigraphy of the Neogene basins of Southern Alföld and their relation to the areas of South Baranya and Yugoslavia. — Bulletin of the Hungarian Geological Society, 304—324.

Füchtbauer, H. [1959]: Zur Nomenklatur der Sedimentgesteine. — Erdöl u. Kohle, *12.* 605—613.

Kertai, Gy. [1957]: The structure of the Hungarian Basins and their oil reservoirs as revealed by the results of oil exploration. — Bulletin of the Hungarian Geological Society. *87.* 384—394.

Krumbein, W. C. [1938]: Korngrösseneinteilungen und statistische Analyse. — N. Jb. Min. Geol. Abh. B. *73.* Stuttgart.

Krumbein, W. C. and Pettijohn, F. J. [1948]: Manual of Sedimentary Petrography. — Appleton—Century—Crofts. Inc. New-York pp. 228—267.

Körössy, L. [1962]: A Nagy Magyar Alföld mélyföldtani és kőolajföldtani viszonyai. — Budapest (Kandidátusi disszertáció) (in Press).

Körössy, L. [1964]: Tectonics of the Basin Areas of Hungary. — Acta Geol. Hung. *VIII.* Budapest, 377—394.

Miháltz, I. [1953]: Le leve geologique de la partie meridionale de l'entre-deux-fleuves Danube-Tisza. — Annual Report of the Hungarian Geological Institute of 1950 Budapest,. 111—143

Miháltz, I. [1953]: La division des sediments Quaternaires de l'Alföld, — Acta Geol. Hung. II. Budapest 109—120.

Miller, R. L.—Kahn, J. S. [1962]: Statistical Analysis in the Geological Sciences. — John Wiley and Sons, New York—London pp. 69.

Molnár, B. [1961]: Die Verbreitung der äolischen Bildungen an der Oberfläche und untertags im Zwischenstromland von Donau und Theiss. — Bulletin of the Hungarian Geological Society *93.* 300—315.

Molnár, B. [1962]: Sedimentpetrographische Untersuchung in Pliozänen und Pleistozänen Ablagerungen is Süden des Ungarischen Tieflandes. — Acta Univ. Szegediensis Acta Miner. —Petr. 43—51.

MOLNÁR, B. [1964]: Sedimentgeologische Untersuchungen in Pliozänen Ablagerungen in Osten des Ungarischen Tieflandes. — Geologische Rundschau *53/2.* 848—866.

MOLNÁR, B. [1964]: On the relationship between the lithology of the abrasion area and the tranported sediments. — Acta Univ. Szegediensis, Acta Miner.—Petr. 69—88.

MOLNÁR, B. [1965]: Beiträge zur Gliederung und Entstehung der jungtertiären und quartären Schichten des Donau-Theiss-Zwischenstromlandes auf Grund der Schwermineralienzusammensetzung. — Bulletin of the Hungarian Geological Society. *95.* 217—225.

MOLNÁR, B. [1965]: Changes in Area and Directions of Stream Erosion in the Eastern Part of the Hungarian Basin (Great-Plain) during the Pliocene and Pleistocene. — Acta Miner. Petr., Szeged 39—52.

MÜLLER, G. [1964]: Methoden der Sedimentuntersuchung. Teil I. E Schweizerbart'sche Verlagsbuchhandlung Stuttgart. pp. 100—104.

NIGGLI, P. [1948]: Gesteine und Minerallagerstätten. Teil I. Verlag Birkhäuser, Basel, 161—165. — Országos Kőolaj- és Gázipari Tröszt jelentései 1950—1964. (in Press) Budapest.

PETTIJOHN, F. J. [1948]: Sedimentary rocks. — Harper E. Brothers Publishers New-York pp. 24—25.

SHEPARD, F. P. [1954]: Nomenclature Based on Sand-Silt-Clay Ratios. Journ. Sedimentary Petr. V. 24. 151—158.

SZABÓ, P. [1955]: Die Entstehungen der oberpleistozänen Sandschichten zwischen Donau und Theiss im Lichte ihrere mineralogischen Zusammensetzung. — Zeitschrift der Ungarischen Geol. Gesellschaft. 442—455.

TRASK, P. D. [1932]: Origin and environment of source sediments of Petroleum, Gulf Publ. Co., Houston.

VENDEL, M. [1959]: A kőzetmeghatározás módszertana. — Akadémiai Kiadó Budapest pp. 472, 546—548.